

On a Static Method of Comparing the Densities of Gases

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Proc. R. Soc. Lond. A 1906 **77**, 542-545

doi: 10.1098/rspa.1906.0047

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results tend to show, if applied without discrimination, that the iron at the low field employed is more sensitive to the co-directional oscillations; but the experimental conditions as regards the transverse oscillations, which latter are produced in a solid mass of metal, and hence are nearly entirely dissipated in the form of eddy currents, are so entirely different from the circular magnetisation obtained by the author's method, in which the value of the magnetisation at the surface of the magnetic wire carrying the oscillations varies inversely as the radius of the wire, that a comparison cannot be made. A combination of the two methods appears to offer additional advantages, but has not yet been tried.

On a Static Method of Comparing the Densities of Gases.

By RICHARD THRELFALL, M.A., F.R.S.

(Received April 3,—Read May 3, 1906.)

The measurement of small differences of pressure to a fairly high degree of accuracy is not difficult. I have indicated a construction of a micro-manometer* which in its ordinary commercial form has a range of 3 or 4 cm. of height of a liquid column and reads to 0.005 mm. direct. Dr. Stanton† describes a manometer constructed on Professor Chattock's principle, having a reading sensitiveness of 0.0015 mm. of water, but the range is not stated. Lord Rayleigh, observing the contact between mercury surfaces and sharp points, obtained a sensitiveness of 0.0005 mm. of mercury with a range of about 1.5 mm.‡

The idea of employing the micro-manometer for the determination of the relative densities of gases first occurred to me in 1901 in considering the corrections to a set of Pitot tube observations taken in a gas pipe situated some 20 feet above the manometer, and though a rough trial was carried out at the time it is only recently that I have had an opportunity of making an adequate test of the method.

Referring to the figure, $A_1 A_2$ are the two limbs of the micro-manometer—the liquid (coloured water or oil) being in communication by the syphon B. The gases whose densities are to be compared are allowed to pass into the long tubes C_1 and C_2 , through the openings at D_1 and D_2 , where there are

* 'Inst. of Meehan. Engin. Proc.,' February, 1904, p. 273.

† Minutes of 'Inst. of Meehan. Engin. Proc.,' vol. 156, session 1903—1904, part 2.

‡ 'Phil. Trans.,' A, vol. 196 (1901), p. 205.

1906.]

Comparing the Densities of Gases.

543

taps. The tubes C_1 and C_2 are formed of ordinary composition gas pipe and are kept at the same temperature by being placed in an outer iron pipe, not shown—through which a current of water passes—the temperature of the water being ascertained by sensitive thermometers.

It is obvious that since the upper openings of the tubes C_1 and C_2 (bent downwards for gases less dense than air) are in the same horizontal plane, the gaseous contents are exposed to the same external pressure, while the pressure in the limbs A_1 and A_2 corresponds to the external pressure, together with the "pneumostatic" pressure due to the height and density of the columns of the gases in the composition pipes. Let the density of the gas in the pipe C_1 be ρ_1 and of the gas in the pipe C_2 — ρ_2 , and let H be vertical distance between the free ends of the composition pipes and the surface of the liquid in the manometer when both pipes are filled with the same gas. Let σ be the density of the liquid in the manometer and h the manometer reading, *i.e.*, the difference of level of the liquid in the two limbs due to the density of the gases being different in the two limbs.

If h is very small compared with H , then it is easy to see (small corrections being omitted) that

$$\rho_2 = \rho_1 - \sigma \frac{h}{H}$$

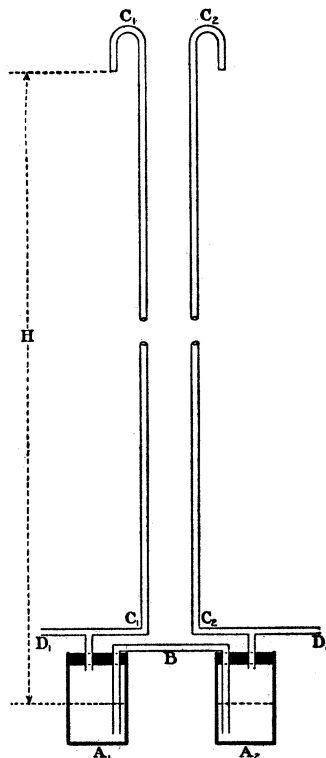
in the case where the pressure at the foot of the tube C_1 is the greater.

The practical limit of accuracy is fixed by the determination of h , and since in the micro-manometer the actual error is independent of the magnitude of h , the experiment must be arranged in such a manner that h is as large as possible.

In the actual experiment a height of nearly 20 metres was available for the gaseous columns.

The accuracy of a comparison is thus easily estimated: suppose that the gases to be compared have about the density of air, that $\sigma=1$, that $h=0.005$ mm. and $H=20$ metres, we have

$$\rho_1 - \rho_2 = \sigma \frac{h}{H} = \frac{0.0005}{2 \times 10^3} = 2.5 \times 10^{-7}.$$



544 Mr. R. Threlfall. *On a Static Method of* [Apr. 3,

The density of air, however, is about 0·00129 gramme per cubic centimetre under standard conditions, so that the smallest difference of density observable by this method is $1\cdot93 \times 10^{-4}$ of the actual density or, say, 1/5000 part.

Lord Rayleigh and Sir William Ramsay* state that the mean of their determinations of the density of "chemical nitrogen" is 1·2511 and of "atmospheric nitrogen" 1·2572 in grammes per litre.

The difference is thus about 1/2100 of the density of the lighter gas. It appears, therefore, that the static method on the scale described should be able to show the difference between the density of "chemical" and of "atmospheric" nitrogen.

Producer gas being lighter than air, it is advantageous to lead it into the column from the top, so that the air in the pipe may be displaced with as little mixing as possible. A preliminary experiment with a rough and ready piece of apparatus has shown that when hydrogen was passed in from the bottom it was very hard to get the column free of air. It is necessary to protect the free ends of the columns from draughts.

In practice, producer or other gas, after passing a suitable drying system, first displaces the air from a large flask which is in communication both with the column and a loosely plugged test-tube—the connection to the latter being by means of about 1 metre of glass tubing of 2 or 3 mm. bore. After a time the flow to the test-tube is stopped and the column filled—the bottom being left open to the air by slipping the rubber tube off the manometer.

The column itself was erected in the angle of a square brick tower, and the height was measured by means of a steel tape—not a method for a classical experiment, of course, but sufficient for the purpose. The water supply was from a large tank at the top of the tower and the water first passed down the tower so as to attain the temperature of the tower as nearly as possible before entering the jacket of the columns. The composition pipes were $\frac{1}{4}$ inch internal diameter, and were strengthened and soldered to the flanged plate where they passed through it. The manometer was at such a height that the free surface of the manometric fluid was at practically the same level as the bottom of the water column. Similarly the open ends of the columns are practically at the level of the top of the water—but as the water and tower were at substantially the same temperature, it was not necessary to be very particular.

The comparison of the densities of producer gas and air appeared to offer no difficulty—everything proceeding "according to arrangement." A set of 20 settings of the micro-manometer showed a probable error of the total of

* 'Phil. Trans.,' A, vol. 186, p. 189.

1906.]

Comparing the Densities of Gases.

545

about 0·00077 mm., and of a single setting 0·0034 mm.; in satisfactory agreement with the opinion formed on instrumental grounds that the error of a single setting might be about 1/200 mm. at most.

The value of h , deduced for the sample of gas used—air filling the other column—was 0·3458 cm., the manometer fluid being distilled water coloured by a trace of aniline blue.

Other data were :—

Height of barometer, corrected for temperature	748·6 mm.
Mean temperature both of water jacket and of tower	18° C.
Height of columns of gas above undisturbed level of micro-	
manometer	1956·8 cm.
Height of manometric column	0·3458 cm.
Density of manometric fluid.....	0·9987

Hence density of producer gas

$$0\cdot001195 - 0\cdot9987 \frac{0\cdot3458}{1956\cdot8} = 0\cdot0010185,$$

or, reduced to 0° C. and 760° mm., the producer gas density is 0·001102 gramme per cubic centimetre.

The gas was most carefully analysed several times and the density calculated from the composition ; the result was :—

Density = 0·001089 gramme per cubic centimetre,

which agrees with the absolute density as nearly as could be expected from an analysis made with commercial apparatus.

Three days later a second experiment was made on the gas which was being manufactured at that date, and a manometer reading of 0·3550 cm. was observed.

This remained constant for several fillings of the columns, and even after they had remained at rest for several hours. The resulting density in this case was 0·001098 gramme per cubic centimetre.

I have pleasure in acknowledging my indebtedness to my assistant, Mr. Bradbury, who carried out the experiment described above.
